
NEW CONTROL APPROACHES DURING VARTM

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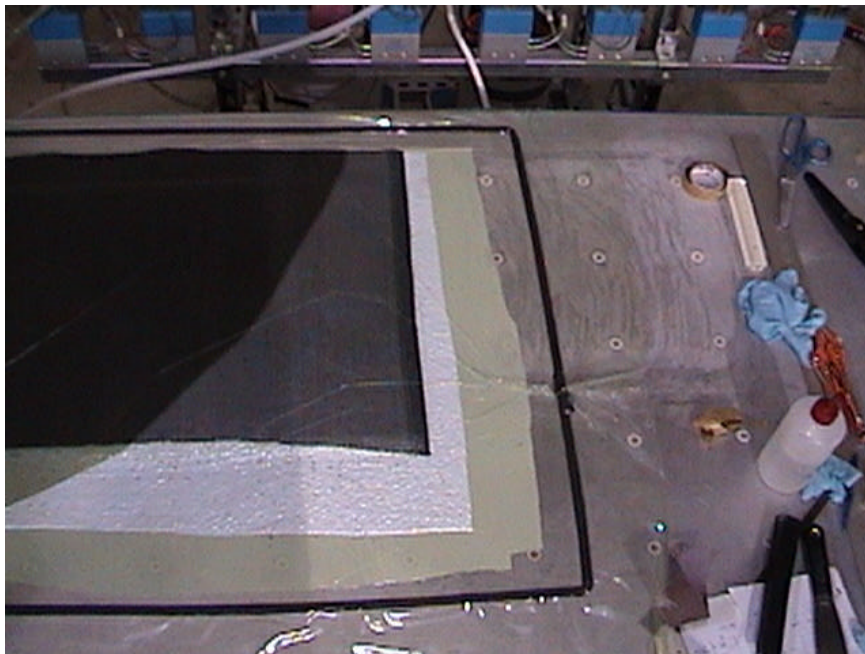
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Overview



- **Background and Objectives**
- **Strategies to Improve VARTM Control**
- **Smart Injection Line**
- **Prototyping and Testing**
- **Summary**

Background



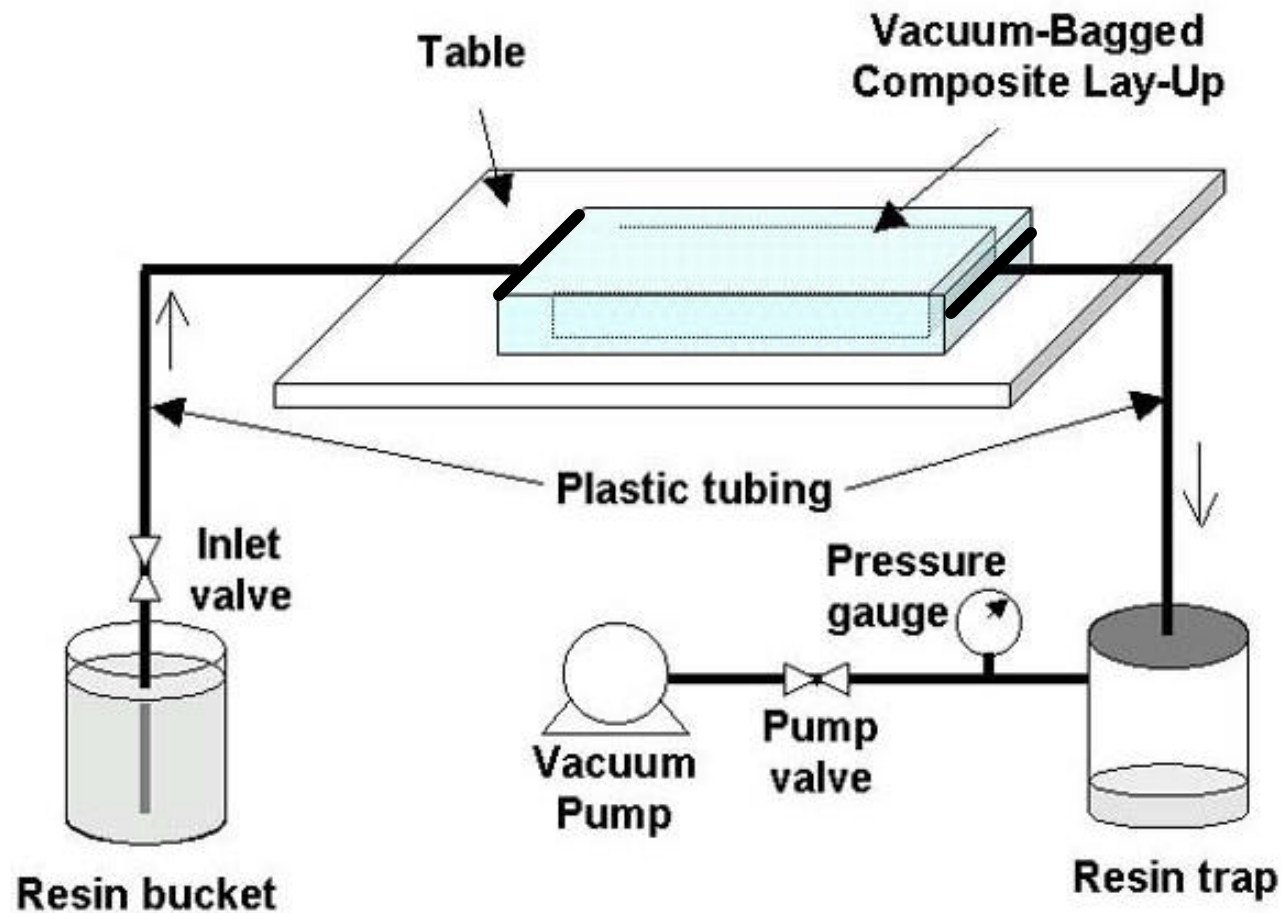
- Need exists to continue to improve part quality
- Dry spots/voids, especially with complex geometries
- Limited control actions available during injection
- Over-compensate
 - ◆ Abundant injection lines
 - ◆ Extended injection times
 - ◆ Trial and error approach for making parts

Goal



- **Improve controllability**
- **Improve part quality, reduce resin waste, and decrease injection for VARTM**
- **Requirements:**
 - ◆ **Flexible**
 - ◆ **Simple**
 - ◆ **Low cost**
 - ◆ **Value**

Improving Control



Improving Control



➤ Current Work with VARTM

- ◆ modeling/simulations of infusion process
- ◆ sensors
- ◆ little work on closed loop control

➤ Limitations

- ◆ pressure gradient fixed
- ◆ line injection
- ◆ fixed, controllable injection points do not exist
- ◆ poor spatial resolution

Improving Control



Previous Work with VARTM

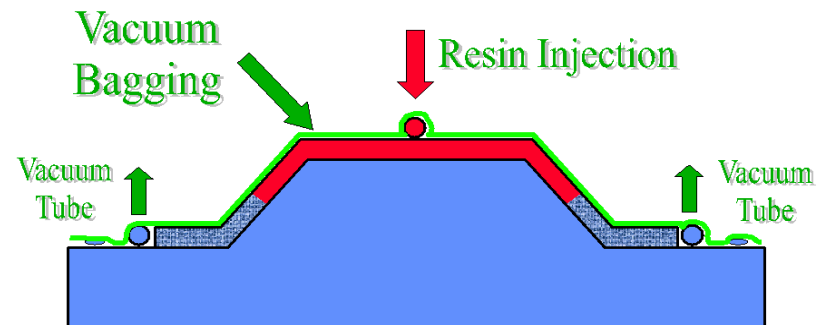
- ◆ On-line control of the resin flow front
- ◆ Real-time modification of resin viscosity via heating
- ◆ Potential changes to flow distribution confounded by premature curing.

Other Possible Control Actions



- **Control Resin Delivery Locations**
- **Control Vacuum Gradient and Lines**
- **Modify Permeability**

Vacuum Assisted RTM



Objectives of this Study



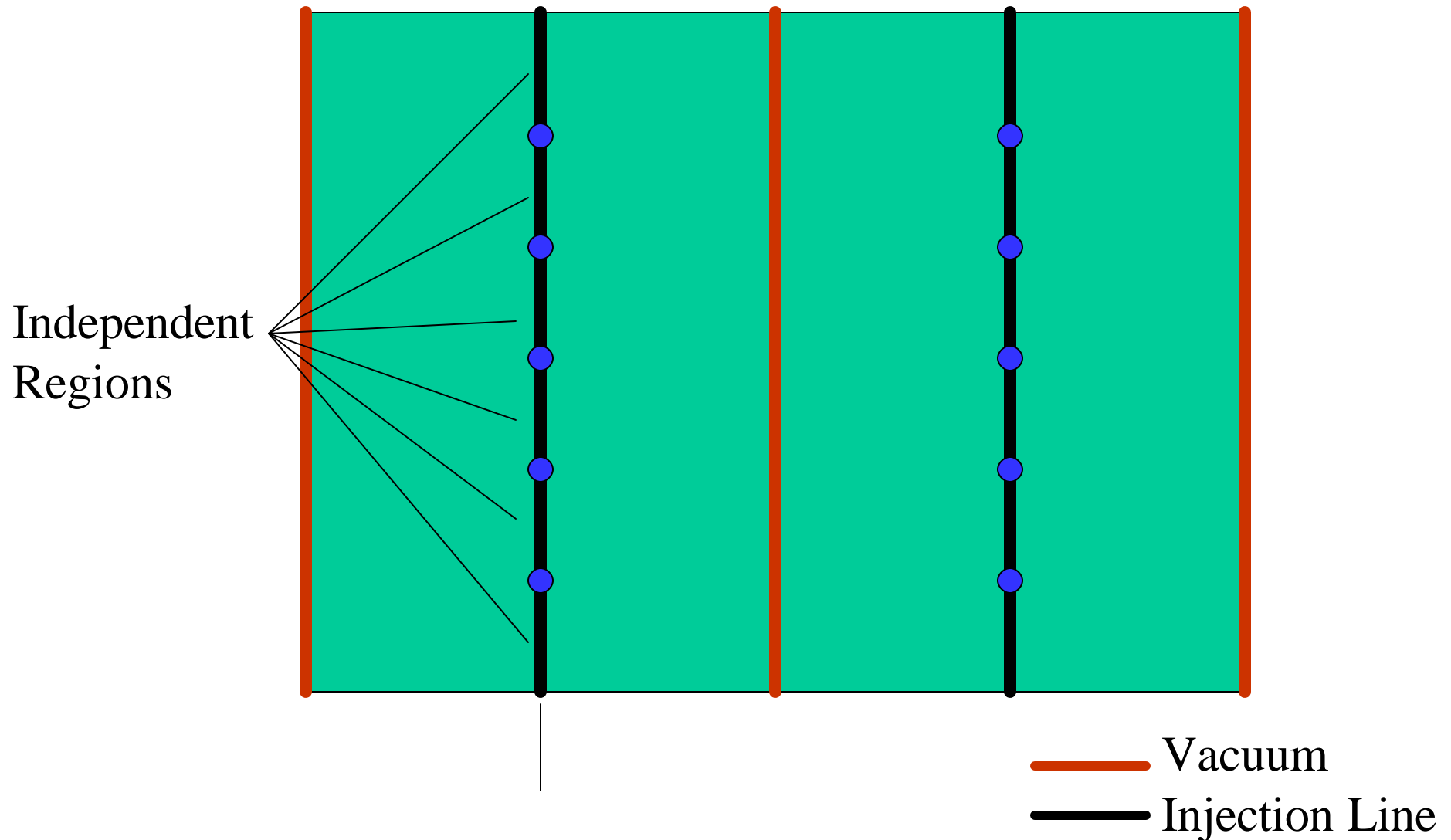
➤ Short-term

- ◆ Prototype a Smart Injection Line with segmented, controllable regions
- ◆ Simulations to determine optimal smart line configurations
- ◆ Simple controller design and testing.

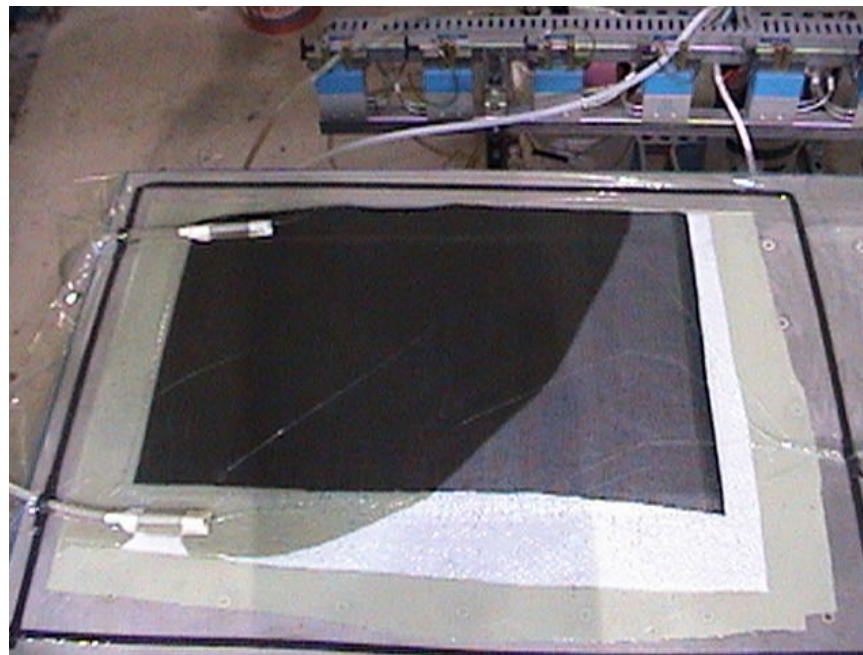
➤ Long-Term Exploration

- ◆ Controllable fibers
- ◆ On-line, real-time modification of the effective porosity of the lay-up
- ◆ Possibility of multi-tasking

Smart Injection Line



Demonstration – Benefits of Smart Line Approach

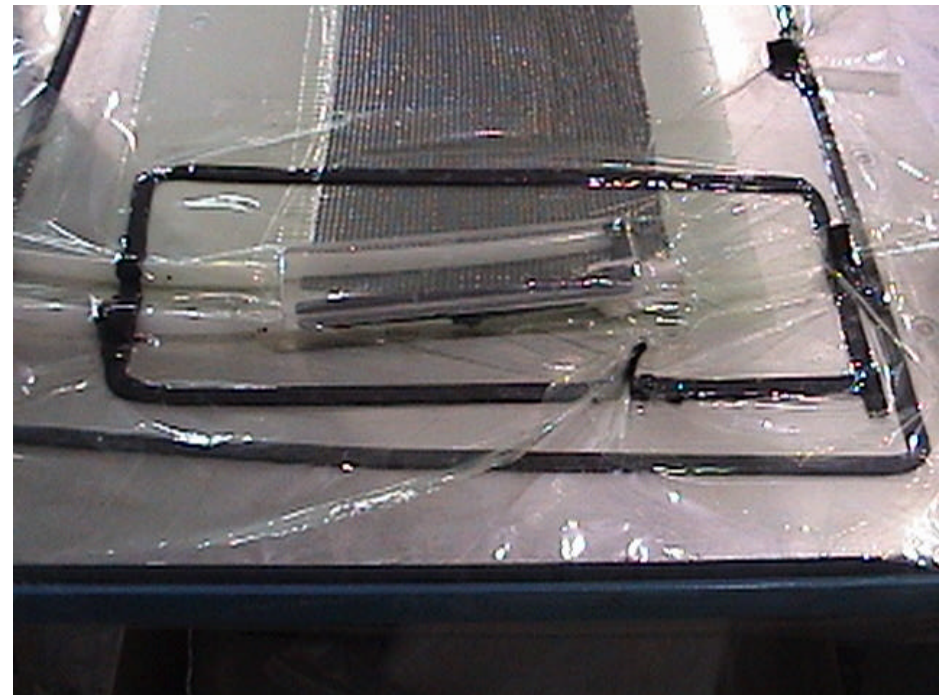
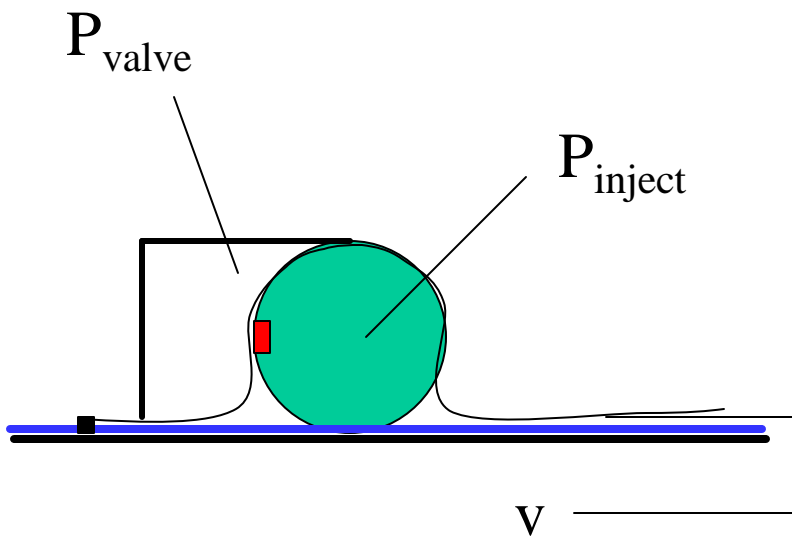


Demonstration – Benefits of Smart Line Approach . . .



Previous Case

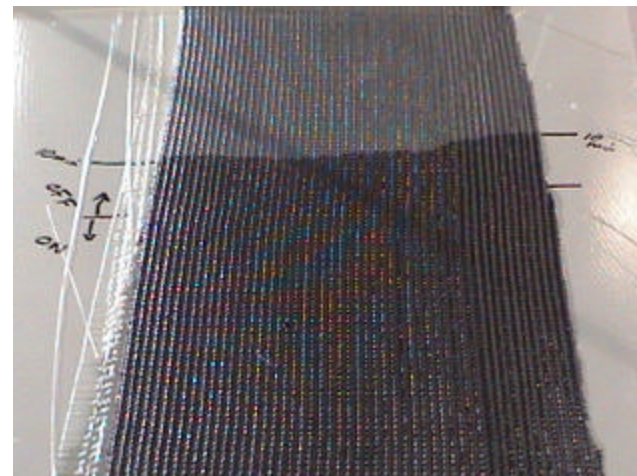
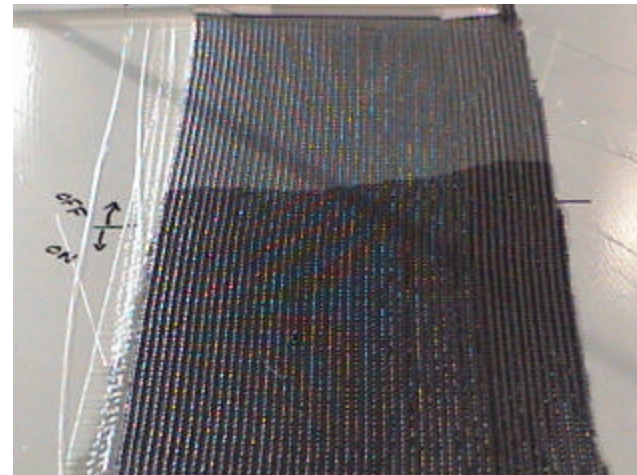
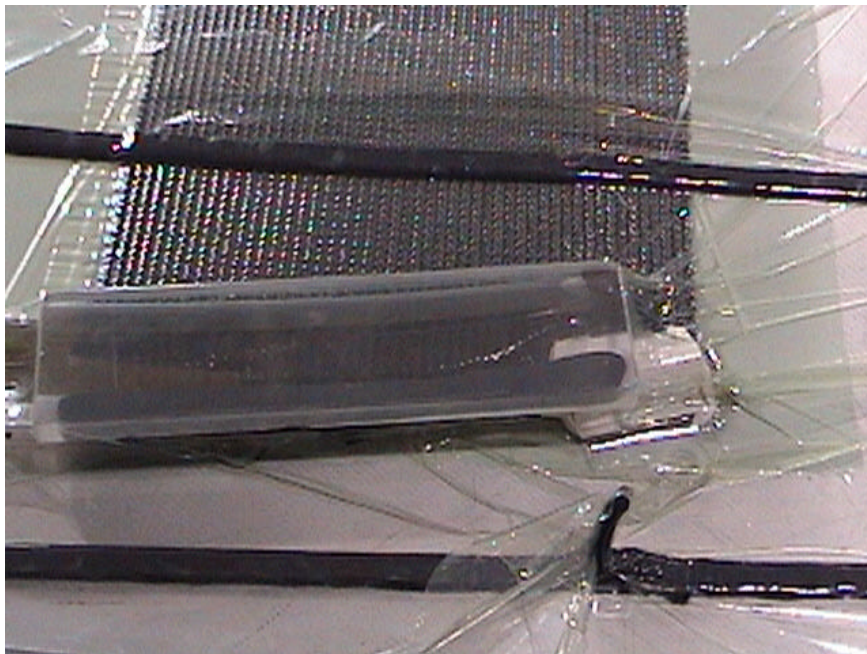
Smart Line – Proof of Concept



if $P_{\text{valve}} < P_{\text{inject}}$, $v = 0$

if $P_{\text{valve}} > P_{\text{inject}}$, $v \neq 0$

Proof of Concept Testing



Current Work



- **Integrate Vacuum “Valve” into the Injection Line Design**
- **Simulations to Determine Best Line Configuration (control segment length, spacing, etc)**
- **Working Prototype by September**

Summary



Improve Control During VARTM

- ◆ **Prototype Smart Injection Line – Vacuum Operated Valves**
- ◆ **Simulate for Optimal Line Configuration and Control**
- ◆ **Develop Complementary Controller Design**
- ◆ **Explore More Sophisticated Methods of Control**